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TEST PAD PROGRAM FINAL REPORT ADDENDUM NO. 1

ON-SITE DISPOSAL FACILITY

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REVISION 0

United States Department of Energy

Fernald Environmental Management Project
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1. INTRODUCTION

The purpose of this Test Pad Program Final Report (TPPFR) Addendum is to modify Section 9 of the TPPFR (GeoSyntec, 1997) by replacing the lower left boundary of the acceptable permeability zone (APZ) with the line of an optimums rather that the 90 percent saturation line. This modification *is* based on variations of materials encountered and lessons learned during Phase I construction of the On-Site Disposal Facility (OSDF) compacted clay liner. Section 9.5 of the TPPFR acknowledged that variations in the clay liner material and the absolute locations of the APZ will occur. A procedure to define the APZ was proposed and used for Phase I construction. A modification in the procedure to define the APZ for each soil source is provided below for approval. Experience gained during Phase I also indicates minor modifications should be made to both the procedures and construction quality control (CQC) protocols used for OSDF compacted clay liner and cap construction.

As a result of the test pad program described in the TPPFR, an APZ was established to provide a compacted clay liner and cap with a maximum hydraulic conductivity of 1×10^{-7} cm/s. The development of the APZ in the TPPFR was based on the well-recognized concept of using the line of optimums for the APZ lower-left boundary. The lower and upper horizon brown till soils used for test pad construction were excavated from an area of limited extent and used in separate test pads. The data obtained from the test pad program exhibited lines of optimums that could be approximated by a 90 percent degree of saturation line. For these soils, a single degree of saturation line was adopted as the lower-left boundary of the APZ for Phase I construction.

The soil used for Phase I compacted clay liner construction exhibited acceptable hydraulic conductivity but had variable standard Proctor compaction curves resulting from variations in material index properties. These variable Proctor curves led to lines of optimums for Phase I clay liner material that ranged from degrees of saturation of about 84 percent to 91 percent. This range is greater than observed during the test pad program and is attributable to natural soil variability encountered throughout the extended area of soil borrow during Phase I. Upon completion of the OSDF Phase I Construction, an evaluation of these variations in clay material indicated an opportunity

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to more efficiently define an APZ for each soil source. Consequently, the line of optimums itself is now recommended as the lower-left boundary of the APZ rather than a single degree of saturation line because it is more representative of the variation in the clay soils used for construction. A representative line of optimums will be applied to each screened material stockpile of approximately 5,000 to 10,000 yd^3 (3,800 to 7,600 m^3).

Improvements to clay liner material processing procedures were also identified and implemented during Phase I. These improvements included mechanical screening for enhanced removal of oversized particles and moisture conditioning during the screening operation to produce a material that is fully hydrated prior to the start of compaction. Moreover, the blending of the material as a result of excavation, processing through the mechanical screen, spreading in the stockpile, excavation from the stockpile, spreading in the cell, and processing with a soil stabilizer resulted in a more homogenous material than was achievable during the test pad program. In recognition of this improved blending, modifications to the CQC clay liner and cap material testing protocols are also recommended herein.

The specific subjects discussed in this addendum are:

- use of the line of optimums to define the lower-left boundary of the APZ;
- implementation of the improved soil processing procedures for enhanced removal of oversized particles and hydration of clay liner and cap material; and
- modification of the procedures and CQC protocols for compacted clay liner and cap construction.

The recommended modifications to the TPPFR are summarized in Section 5 of this TPPFR Addendum.

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2. LINE OF OPTIMUMS

2.1 Background

Substantial evidence has been documented in the geotechnical literature to show that the key to achieving a hydraulic conductivity less than 1 x 10^{-7} cm/s in a compacted clay liner or cap is to ensure that the compaction moisture content and dry unit weight plot above the line of optimums. Benson and Boutwell (1992) analyzed data on hydraulic conductivity of compacted clay liners relative to the compaction criteria employed during construction for a number of sites. They concluded that the "criterion used to control construction should ensure compaction wet of the line of optimums". Current USEPA (1993) guidance advocates using the line of optimums for compaction control as part of the CQC protocol for compacted clay liners and caps.

2.2 Lessons Learned During OSDF Phase I Construction

The APZ presented in the TPPFR was developed to assure that the soil material used for the OSDF compacted clay liner and cap was compacted to a state at or above the line of optimums. For simplicity, that line of optimums was approximated by a single degree of saturation line of 90 percent. The 90 percent degree of saturation line was chosen as an approximation to the line of optimums for both upper and lower horizon brown till based on the results of standard (ASTM D 698) and modified (ASTM D 1557) Proctor compaction tests performed during the OSDF test pad program. These test results are presented in Figure 2-1 where the close correlation between the lines of optimum and 90 percent degree of saturation line can be observed.

The soil materials used for Phase I compacted clay liner construction exhibited lines of optimum that typically ranged from degrees of saturation of about 84 percent to 91 percent. These results represent a larger range in Proctor compaction test results than observed in the lower and upper horizon brown till used for the test pad program. To illustrate this variability, the peaks of the various standard Proctor compaction curves obtained during Phase I liner system construction are plotted on a dry unit weight versus moisture content graph in Figure 2-2. Contours representing constant degrees of saturation are also shown in Figure 2-2 in order to estimate how these standard Proctor compaction peaks relate to the degree of saturation. It should be noted that the material used for Phase I liner system construction was excavated from an area much larger, and soils were more variable, than that available during the test pad program. Also, the soils were mixed during stockpiling and blended during screening, which did not occur during the test pad program.

2.3 Recommended APZ

During future phases of OSDF construction, material for compacted clay liner and cap construction will be excavated from the footprint of various OSDF cells and the OSDF borrow area. The variability of these soils is expected to be as great as the variability observed during Phase I construction. In recognition of this variability, it is recommended that the lower-left boundary of the APZ be defined by the line of optimums for the clay material to be compacted and not by a single degree of saturation line. This recommendation is consistent with the results of the original test pad program and with recommendations in the geotechnical literature. This recommendation will allow natural variability of soils used for OSDF compacted clay liner and cap construction.

ACCEPTABLE PERMEABILITY ZONE (APZ) TEST PAD PROGRAM FINAL REPORT

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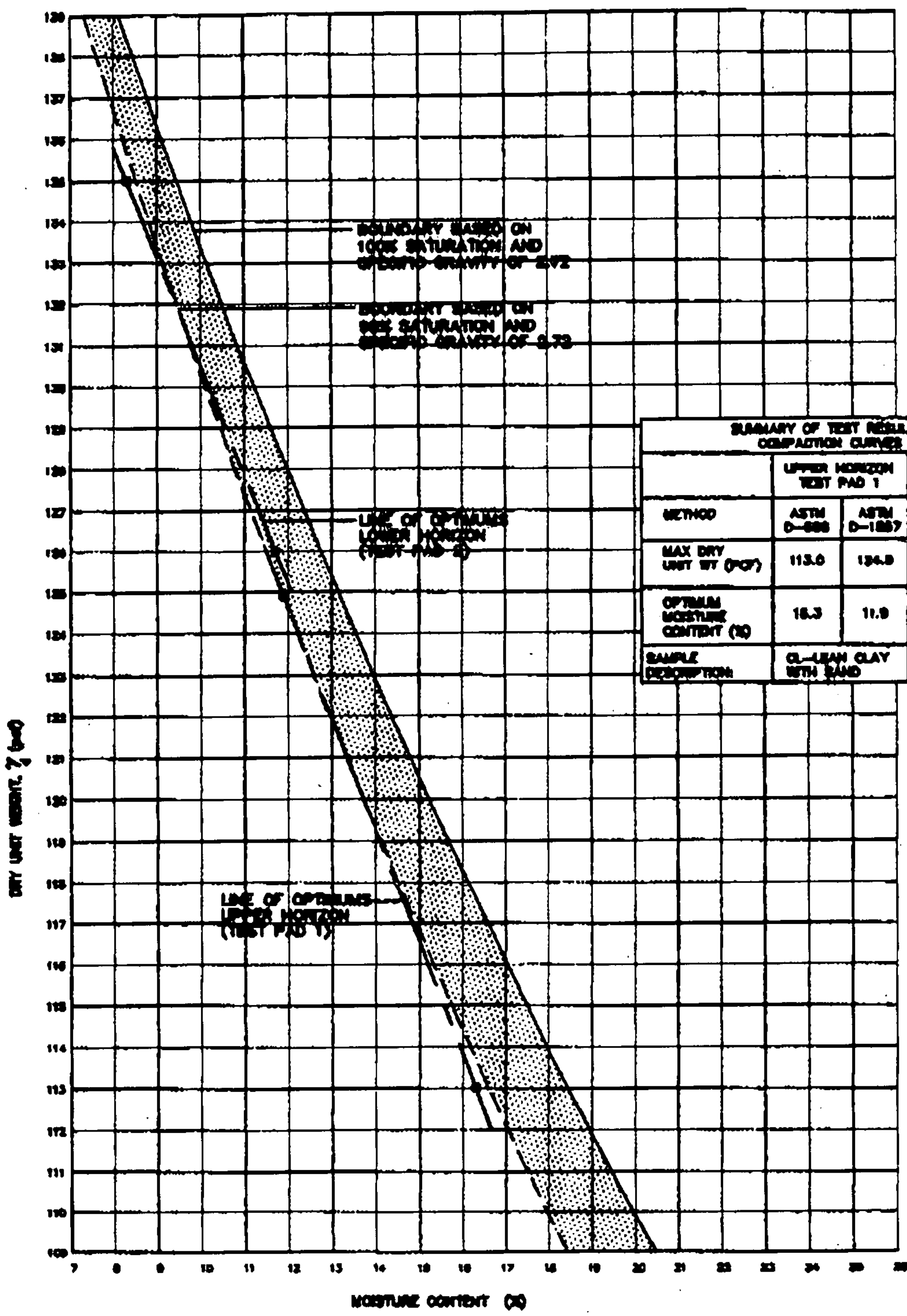

SUMMARY OF TEST RESULTS COMPACTION CURVES				
	UPPER HORIZON TEST PAD 1		LOWER HORIZON TEST PAD 2	
METHOD	ASTM D-698	ASTM D-1557	ASTM D-698	ASTM D-1557
MAX DRY UNIT WT (PCF)	113.0	124.8	126.0	135.0
OPTIMUM MOISTURE CONTENT (%)	16.3	11.9	11.7	8.3
SAMPLE DESCRIPTION:	CL-LEAN CLAY WITH SAND		CL-SANDY LEAN CLAY WITH GRAVEL	

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FIGURE NO.	2-1
PROJECT NO.	GQ0409-05
DOCUMENT NO.	
FILE NO.	0409F104

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PEAKS OF STANDARD PROCTOR CURVES
PHASE I OSDF CONSTRUCTION

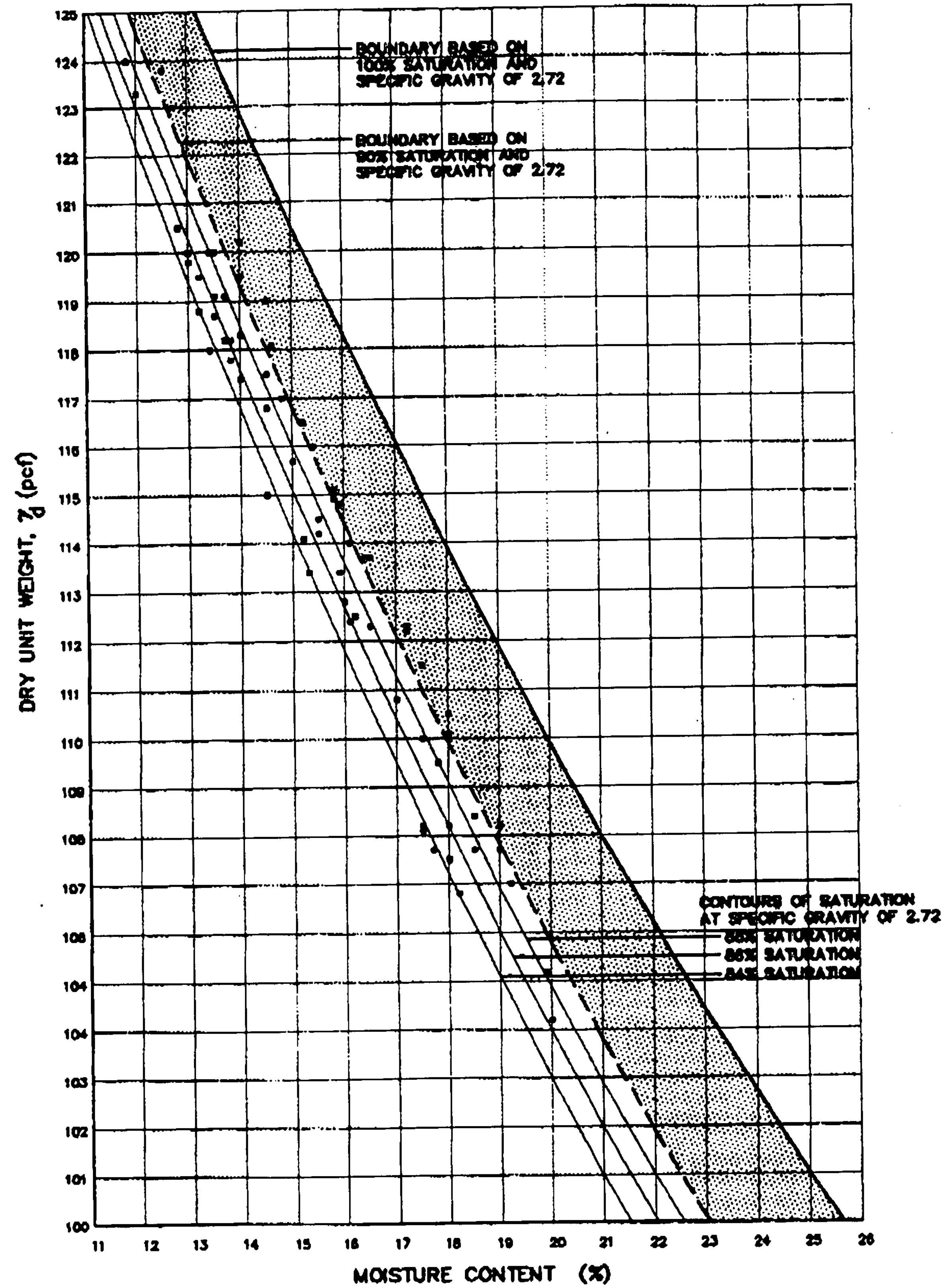

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FIGURE NO.	2-2
PROJECT NO.	GQ0409-05
DOCUMENT NO.	
FILE NO.	0409F101

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3. SOIL PROCESSING

3.1 Background

Adequate processing, which includes screening, blending, and hydration of clay liner and cap materials, is also important to achieving low field hydraulic conductivity. Benson et al. (1997) described a hydraulic conductivity assessment that was conducted on four test pads constructed to the same specifications with soil from the same source by four different contractors. The test pads had distinctly different field hydraulic conductivities, even though they were constructed with similar soil, to similar compaction conditions, and with similar machinery. An analysis of these differences showed that adequate hydration time was crucial in achieving low hydraulic conductivity and that soil blending was another important factor responsible for low hydraulic conductivity. As discussed below, lessons learned during Phase I construction are consistent with these recently published technical findings.

3.2 Lessons Learned During OSDF Phase I Construction

The TPPFR recommended soil processing to be accomplished by means of a soil stabilizer making a minimum of two passes through each loose lift thickness during construction of the compacted clay liner or cap. During construction of the compacted clay liner in Phase I, mechanical screening was implemented to enhance removal of particles greater than 2 in. (50 mm) in maximum dimension. This mechanical screening provided a secondary benefit of improved soil blending. The blending of the material as a result of excavation, processing through the mechanical screen, spreading in the stockpile, excavation from the stockpile, spreading in the cell, and processing with a soil stabilizer resulted in a more homogenous material than was achievable during the test pad program.

As an integral part of mechanical screening, water was applied to the screened clay material by means of a spray bar at the end of the stacking conveyor. The addition of water prior to stockpiling of the clay material allowed hydration times of 24 hours or more prior to final processing and compaction in the cell. These improved material processing procedures produced a blended material which was fully hydrated prior to the start of compaction and minimized the need for addition of water in the cell. This also provides a secondary benefit of dust control.

3.3 Recommended Soil Processing

It is recommended that procedures proven during construction of the Phase I compacted clay liner continue to be used for future OSDF clay liner and cap construction. The construction contract should include the following requirements.

- A mechanical screening operation, similar to that used during Phase I, should be implemented to remove particles greater than 2 in. (50 mm) in maximum dimension.
- Water should be added to the clay material as the material is discharged from the screening operation to the stockpile. Water should be added in a manner that: (i) assures uniform moisture distribution; and (ii) results in an acceptable range of soil moisture content for compaction within the cell.
- Mechanically screened material should be placed in stockpiles sized between 5,000 and 10,000 yd^3 (3,800 to 7,600 m^3).
- Clay material should be allowed to hydrate in the stockpile prior to use in compacted clay liner or cap construction.

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4. CQC TESTING PROTOCOLS

A single APZ was developed during the test pad program to represent the line of optimums for the upper and lower horizon brown till soil used in test pad construction. In recognition of the variability of the material excavated from a larger area during actual OSDF construction, the establishment of individual APZs for each mechanically-screened and moisture-conditioned stockpile is now recommended. Because of the need to establish a line of optimums for each soil stockpile, it is recommended that existing CQC testing protocols be modified to include the following steps.

- As per applicable or relevant and appropriate requirement (ARAR), the CQC consultant should perform one standard Proctor compaction test (ASTM D 698) per 1,500 yd^3 (1,140 m^3) of material or a minimum of two tests per screened stockpile and one modified Proctor compaction test (ASTM D 1557) per two standard Proctor compaction tests.

- The optimum moisture content and maximum dry unit weights obtained from the standard Proctor compaction tests for each stockpile should be averaged (arithmetic means) to obtain a representative stockpile standard Proctor optimum moisture content and maximum dry unit weight; the same averaging process should be used with the modified Proctor compaction test results to obtain a representative stockpile modified Proctor optimum moisture content and maximum dry unit weight; the averaged standard and modified Proctor test results should be used to develop a stockpile-specific line of optimums.

- After the stockpile-specific line of optimums is developed, individual standard and modified Proctor optimum points for the stockpile will be plotted and compared to the line of optimums. This comparison is to identify potential outliers. Outliers are defined as points more than 2 moisture percentage points away from the corresponding line of optimums moisture percentage. If an outliner is identified, an additional soil sample from the same vicinity in the stockpile as the outlier sample will be collected and tested. The optimum point for the additional sample will be substituted for the outlier and a stockpile-specific line of optimums will be developed. The outlier identification process

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described above will be repeated. If another outlier is identified, the stockpile will have demonstrated unacceptable variability for clay liner and cap construction and will be used for other construction purposes.

- The APZ for each clay material stockpile should be defined by the following boundaries:
  - a moisture content not greater than 3 percentage points wet of the standard Proctor optimum moisture content;
  - a lower-left boundary defined by the line of optimums; and
  - a lower boundary of at least 95 percent of the standard Proctor maximum dry unit weight.
- The CQC Consultant should perform one remolded hydraulic conductivity test (ASTM D 5084) per stockpile to verify the APZ. Material used for the test should be composited from all samples and remolded to a target dry unit weight of a minimum of 95 to 98 percent of the representative standard Proctor maximum dry unit weight at a target moisture content of 0 to 1.0 percentage points wet of the line of optimums.

The CQC Consultant should plot the APZ on a graph moisture content versus dry unit weight to define the compaction conditions for each material stockpile. Figure 4-1 presents a standard form for plotting dry unit weight versus moisture content. Figure 4-2 presents an example of an APZ for a stockpile with average standard Proctor maximum dry unit weight of 106.8 lb/ft^3 (16.8 kN/m^3) and optimum moisture content of 18.2 percent and average modified Proctor maximum dry unit weight of 121.1 lb/ft^3 (19.0 kN/m^3) and optimum moisture content of 13.1.

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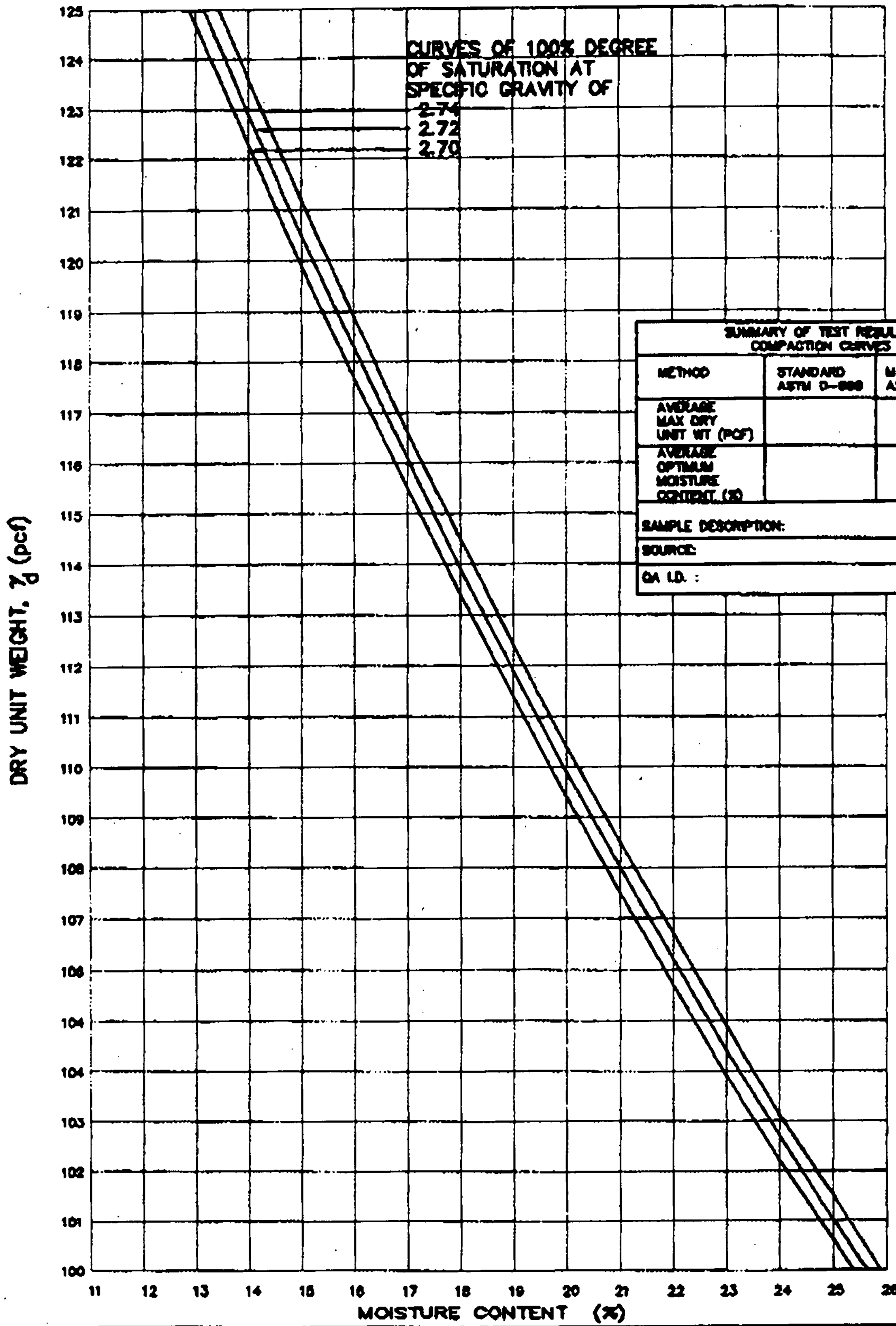
FIELD FORM FOR ESTABLISHING ACCEPTABLE PERMEABILITY ZONE (APZ) BASED ON LINE OF OPTIMUMS



SUMMARY OF TEST RESULTS COMPACTION CURVES		
METHOD	STANDARD ASTM D-698	MODIFIED ASTM D-1557
AVERAGE MAX DRY UNIT WT (PCF)		
AVERAGE OPTIMUM MOISTURE CONTENT (%)		
SAMPLE DESCRIPTION:		
SOURCE:		
QA I.D. :		

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FIGURE NO.	4-1
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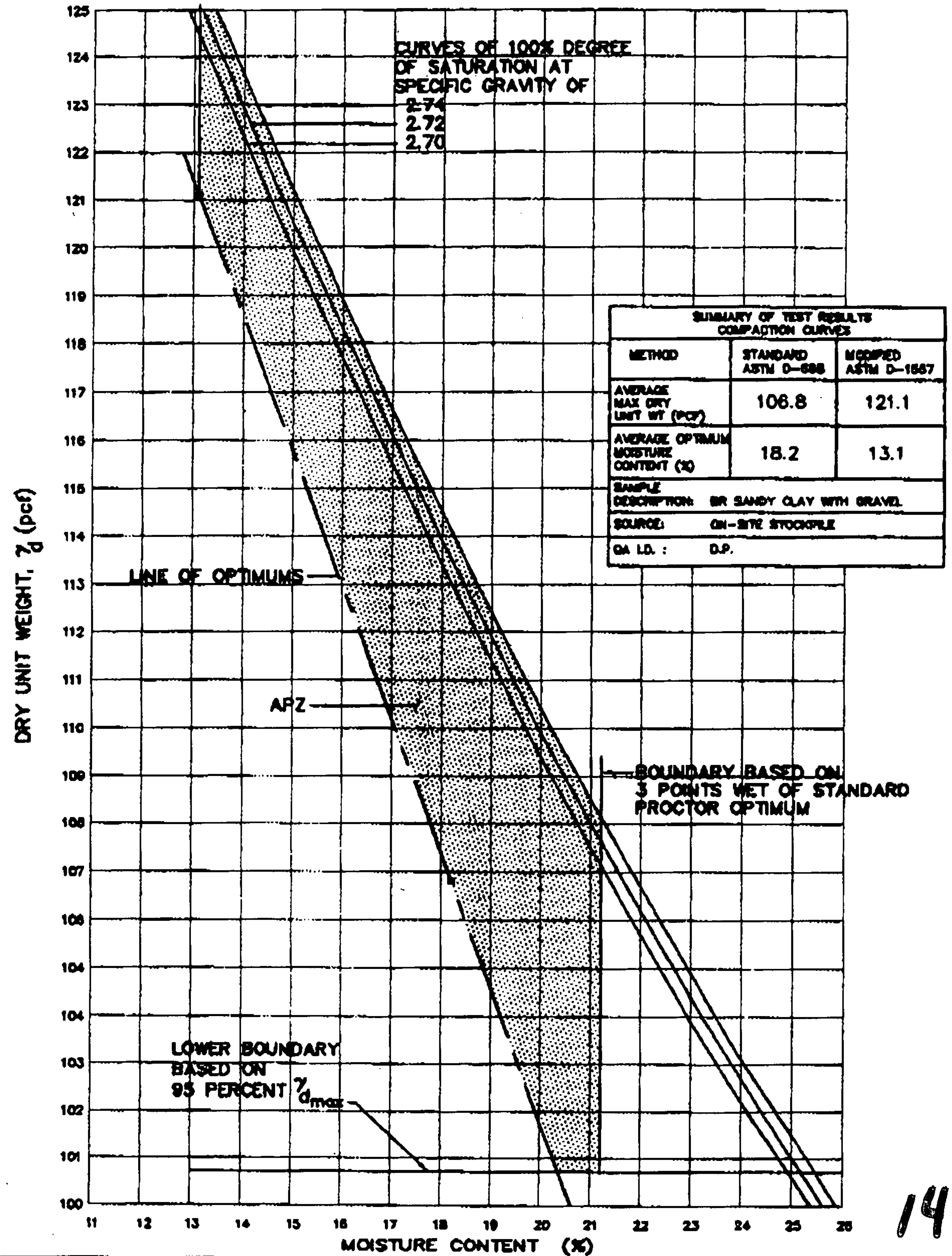
EXAMPLE OF ACCEPTABLE PERMEABILITY ZONE (APZ) BASED ON LINE OF OPTIMUMS



SUMMARY OF TEST RESULTS COMPACTION CURVES		
METHOD	STANDARD ASTM D-698	MODIFIED ASTM D-1557
AVERAGE MAX DRY UNIT WT (PCF)	106.8	121.1
AVERAGE OPTIMUM MOISTURE CONTENT (%)	18.2	13.1
SAMPLE DESCRIPTION: BR SANDY CLAY WITH GRAVEL		
SOURCE: ON-SITE STOCKPILE		
QA I.D. : D.P.		

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FIGURE NO.	4-2
PROJECT NO.	GQ0409-05
DOCUMENT NO.	
FILE NO.	0409F103

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5. MODIFIED RECOMMENDATIONS

5.1 Oversized Particle Removal

Section 9.2 of the TPPFR, titled Compacted Clay Material Criteria, recommends continuous removal of visible rock particles with a maximum dimension greater than 2 in. (50 mm) during clay material placement, processing, and compaction. The continuous process of removing oversized particles should be continued. This TPPFR Addendum additionally recommends that mechanical screening, as implemented during Phase I construction, continue to be used to enhance removal of oversized particles and to improve the production of a blended clay material for OSDF compacted clay liner and cap construction.

5.2 Borrow Material Preparation and Placement Procedures

Section 9.3 of the TPPFR, titled as above, recommends clay material pre-processing and moisture conditioning be accomplished using a transverse rotary mixer with spray bar. This TPPFR Addendum additionally recommends that water addition at the end of mechanical screening and prior to stockpiling, as implemented during Phase I construction, continue to be used to promote adequate hydration of clay material prior to use of the material for OSDF compacted clay liner and cap construction.

5.3 Acceptable Permeability Zones for Construction

Section 9.5 of the TPPFR, titled as above, recommended the use of the lower-left boundary of the APZ as the 90 percent degree of saturation line. As previously discussed in this report, this degree of saturation line was adopted because the lower and upper horizon brown tills used in the test pad program exhibited lines of optimums that could be approximated by a 90 percent degree of saturation (see Figure 2-1).

The soil materials used for Phase I compacted clay liner construction exhibited acceptable hydraulic conductivities and had variable standard Proctor compaction curves, many of which were lower than a 90 percent degree of saturation line. This

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variability is attributed to natural soil variability encountered throughout the extended area of soil borrow during Phase I. This same variability is expected for future phases of OSDF compacted clay liner and cap construction. In recognition of this variability, this TPPFR Addendum recommends that the line of optimums itself be used as the lower-left boundary of the APZ. This TPPFR Addendum further recommends that a stockpile-specific representative line of optimums be applied to each processed material stockpile. It is recommended that stockpiles be developed with 5,000 to 10,000 yd^3 (3,800 to 7,600 m^3) volumetric capacity.

6. REFERENCES

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